LMDS Power Generation Capability
28 GHz vs 40 GHz

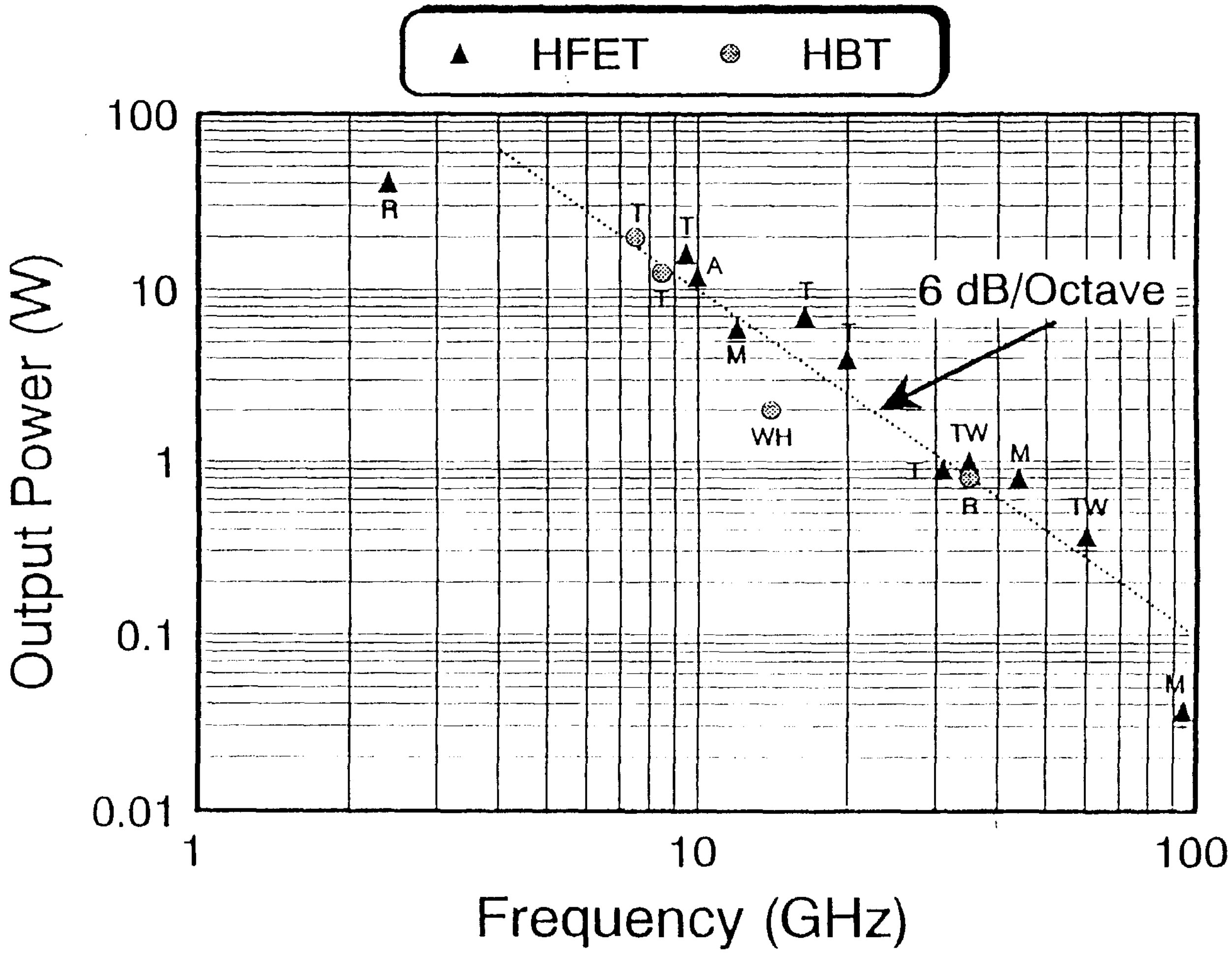
- The current power generation capability using P-HEMT solid state devices is

  30 dBm (1 watt) at 28 GHz and

  22-24 dBm (150 to 250 milliwatts) at 40 GHz.
- Ten year history of solid state device capability indicates approximately 1 watt limit at 28 GHz and 27 dBm (0.5 watt) limit at 40 GHz, (power vs frequency figure).
  - Device power capability is a function of active device size/area, current density limits and maximum device operating temperature for a given level of device reliability.

40 GHz Power Amplifiers will cost more than twice that at 28 GHz

Ten Year History of Solid State Device Power Capability



T: TI R: Raytheon A: Avantek/HP M: Martin Marietta TW: TRW WH:Westinghouse

Frequency Generation
40 GHz Stability and Noise

- Frequency signal generation at 40 GHz will have half the stability and 1.4 times more phase noise than a 28 GHz frequency synthesizer.
  - Required wider channels at 40 GHz
  - More complex frequency/signal generation to support dual up/down converters in the node and CPE's.

40 GHz frequency signal generation are estimated to be 1.8 to 2.5 more cost than 28 GHz systems

CPE Noise Figure/Down Converter
28 GHz vs 40 GHz

- CPE's at 28 GHz can achieve a receiver 8 dB noise figure without a low noise amplifier, (LNA).
- Device/LNA noise figures normally quoted are for single frequencies not for 1 GHz bandwidth.
  - Single frequency device NF's of 6 dB are available for 40 GHz.
  - Broadband LNA noise figures are in the 8 dB range.
- To achieve an 8 dB CPE noise figure requires an LNA.

A 40 GHz LNA with 8 dB NF would add $50 cost to each CPE

LMDS Rain Attenuation
28 GHz vs 40 GHz

- The link budget accommodates 3.7 dB/Km attenuation from 21 mm/hr rain rates for 99.7% availability during the worse rain months in the United States.
- At 40 GHz 21 mm/hr rain rates will produce 6.3 dB/KM. [1]
- For a 5 Km system the additional 13 dB attenuation at 40 GHz will require the system to compensate by
  - Increasing the node/CPE transmitter power,
  - Lower receiver noise figure at the node and CPE,
  - Increase CPE antenna gain, and
  - Reduce the node/hub operating radius.

[1] Prediction of Attenuation by Rain, Robert K. Crane, IEEE Transactions on Communications, Vol. Com-28, No. 9, September 1980.

LMDS ECONOMIC ISSUES
AT
28 GHz VS 40 GHz

LMDS Economic Issues at 28 GHz vs 40 GHz

- Increased cost of node and CPE equipment at 40 GHz.
- Increased cost per subscriber due to equipment cost and subscriber base, (node radius reduction).

LMDS 40 GHz Cost Model/Indices - Equipment

- Hub/node coverage area (5 Km radius/16,000 subscribers) the same as 28 GHz system. [1]

NOT A PRACTICAL ASSUMPTION FOR IMPLEMENTATION

Cost Model/Indices	40 GHz	40/28 GHz	Cost Factor
• LMDS Subscriber cost Indices	100	121.3	1.21
–CPE	83.3	101.1	1.12
• Antenna/electronics	26.7	32.4	1.53
• Terminal	26.4	32.1	1.0
• Set top box	30.2	36.6	1.0
–Node	13.1	15.8	2.73
• RF System	11.0	13.4	4.0
• Telecom	1.7	2.0	1.0
• Video	0.3	0.4	1.0
–Central Network	3.5	4.4	1.0

[1] Requires compensation in the system design to accommodate 3 dB loss of range due to frequency move, 13 dB increase in rain attenuation and 3 dB less power per microwave P-HEMT device.

LMDS 40 GHz System Trades

- Increased attenuation
  - Rain attenuation (40 GHz, 21 mm/hr) 6.3 dB/Km
  - Space loss (40 GHz) 3 dB
- Assume the same power output as 28 GHz, (30 dBm/ channel) and an antenna gain increase of 6 dB, (40 dB vs 34 dB)
- A node radius of 1.9 Km along with the CPE antenna gain increase has sufficient improvement in space loss (vs 5 Km) to offset the increased rain the frequency space loss at 40 GHz.
- Node coverage area with 1.9 Km radius is 11.34 Km^2.
- A 1.9 Km radius covers 2,325 subscribers with a 205 subscriber/ Km^2 density.
- Cost per subscriber increase is ~6.9X.

LMDS 40 GHz Cost Model/Indices - Reduced Coverage [1.9Km]

- Hub/node coverage area (1.9 Km radius/2,300 subscribers) is reduced from the 28 GHz system (5 Km radius/16,000 subscribers)

Subscriber Cost Indices	40/28 GHz
LMDS Subscriber cost Indices	214.5
– CPE	101.1
• Antenna/electronics	32.4
• Terminal	32.1
• Set top box	36.6
– Node	109.0
• RF System	92.4
• Telecom	13.8
• Video	2.8
– Central Network	4.4

LMDS Cost Model/Indices Per Subscriber Summary

System	28 GHz	Equipment 40/28 GHz	Reduced R (1.9 Km) 40/28 Hz[1]
• LMDS Subscriber cost Indices	100	121.3	214.5
–CPE	90	101.1	101.1
• Antenna/electronics	21	32.4	32.4
• Terminal	32	32.1	32.1
• Set top box	37	36.6	36.6
–Node	6	15.8	109.0
• RF System	3	13.4	92.4
• Telecom	2	2.0	13.8
• Video	1	0.4	2.8
–Central Network	4	4.4	4.4

[1] Practical 40 GHz LMDS system

28 GHz Interference/Coshare Issue

- FSS interference into a nearby LMDS receiver can be significant due to the FSS power levels.
- A good example is that of a Teledesic TST with the following parameter:
  - TX Power 19.1 dBw (heavy rain)
    2.1 dBw (clear sky)
  - Antenna Gain 36 dB
  - EIRP 55.1 dBw (heavy rain)
    38.1 dBw (clear sky)
  - Sidelobe (40°) -38.5 dBw
- The above parameters require the LMDS receiver to contend with interference levels ranging from 16.6 dBw/46.6 dBm, (heavy rain) to -0.4 dBw/29.6 dBm, (clear air).
- For LMDS receivers which require interference to be at or below -95 dBm to prevent degradation requires significant reduction (158.6 dB to 175.6 dB) in the offending signal to prevent LMDS system degradation.

SUMMARY

- Texas Instruments is an active developer of advanced communications technologies, including equipment for 28 GHz digital LMDS, to support the Nation's emerging digital wireless infrastructure.

- TI's 28 GHz digital LMDS technology will enable a wide variety of broadband, two-way video, telephony, and data transmission services.

- LMDS would be burdened with severe technical and economic penalties if authorized at 40 instead of 28 GHz.

  - Reduced coverage at 40 GHz due to increased space loss and rain attenuation would increase the cost and hinder the performance of distribution nodes.

  - 40 GHz LMDS subscriber units would cost up to twice as much as 28 GHz systems.

- Development of 40 GHz components and equipment would delay significantly the introduction of LMDS.

- LMDS-FSS sharing at 28 GHz is difficult but not impossible.

  - The negotiated rulemaking did not conclude otherwise.

  - The Bellcore study indicates there are potential LMDS-FSS sharing solutions at 28 GHz. Identification of a precise solution will require additional consideration of FSS modulation formats and operational characteristics.

  - The LMDS sharing arrangement with Motorola's Iridium system suggests that LMDS-FSS sharing at 28 GHz is possible if parties want it.

- If no sharing solution is found, TI would support a service auction in the 28 GHz band.

Conclusions

- FSS terminals operating near LMDS CPE's can create significant harmful interference that would require mitigation at the source.
- Technical and economic issues are created by moving LMDS from 28 GHz to 40 GHz.
- Development of 40 GHz components (P-HEMT devices) and equipment would delay LMDS significantly
- Reduced operating range/coverage area resulting from increased space loss and rain attenuation at 40 GHz have significant impact on system cost and performance.
- TI's 28 GHz digital LMDS system offers the most efficient use of the spectrum and offers the greatest public benefit as compared to the limited capacity of the FSS systems.